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# THE USE AND CALIBRATION OF THE 'MAXWELLIAN VIEW' IN VISUAL INSTRUMENTATION

The radiant energy reflected by or emitted from a surface diverges in all directions.[1] In order to be effective visually, this energy must pass through the entrance pupil of the eye after which, assuming adequate dioptrics, it will be focused on the retina. The size of the light pencil emanating from a given object point which reaches the corresponding image point on the retina is proportional to the pupil diameter. The larger the pupil diameter (or the light pencil) the more energy from the object point will be able to reach its corresponding image point and the 'brighter' the point will appear. The entrance pupil of the eye can, however, intercept only a small fraction of the energy from a diffuse surface, and consequently most of the emitted energy does not enter the eye and is therefore not effective visually (Fig. 1A).

In order to present an extended test-field of high luminance, the 'Maxwellian view'

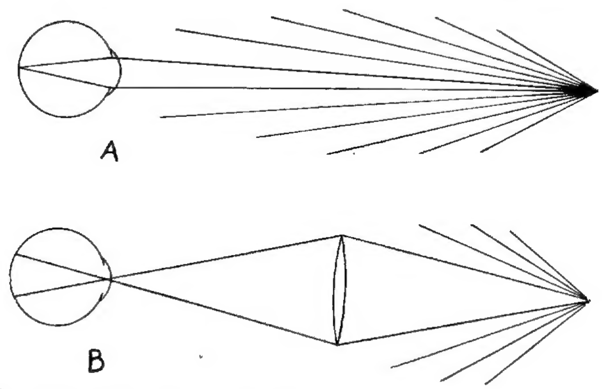


FIG. 1. DIAGRAM ILLUSTRATING THE EFFICENCY OF THE 'MAXWELLIAN VIEW'
A, unaided eye, only the light intercepted by the pupil reaches the retina; B, Maxwellian view, all the light intercepted by the lens enters the eye.

is frequently used in visual instrumentation.[2] The principle of the Maxwellian view is to focus the image of a light source in the plane of *S*'s pupil (see Fig. 1B). All the light intercepted by the lens enters the eye as contrasted with Fig. 1A where

[1] The author wishes to express his appreciation to Dr. C. S. Bridgman for his effective aid in the preparation of this note.

[2] Named in honor of J. Clerk Maxwell who utilized this principle in the construction of his color-mixing apparatus. (See Maxwell, On the theory of compound colors and the relation of the colors of the spectrum, *Phil. Trans.*, 150, 1860, 57.)

forms a conjugate image of the source with unit magnification at some distance away from the eyepiece of the apparatus). Alternative procedures for the calibration of the Maxwellian view which permit the photometer to be used on diffuse surfaces are indicated below.

A convenient technique for calibration of the Maxwellian view is to cover one half of the field lens with a mirror positioned so as to reflect the image of a diffuse surface in the direction of *S*'s eye. *S* then sees a bipartite field, one half of which is supplied by the Maxwellian view field lens and the other half by the image of the diffuse surface seen in the mirror. The two halves of the field lens are matched by adjusting the luminance of either component after which a calibration value is obtained in the usual manner from the diffuse surface. As in the calibration method discussed above, the effective entrance pupil must be the same size for the Maxwellian and the diffuse fields.[6]

In the binocular method *S* observes the field of the Maxwellian view with one eye and a diffuse surface of the same size with the other eye. By adjusting convergence, the two fields may be made to appear in juxtaposition. After being matched for equality, the luminance is determined with a conventional photometer from the diffuse surface. It is necessary, of course, that the entrance pupils of the two eyes be equal. The facility with which this binocular match can be made is improved by providing for a common boundary between the two fields. This can be accomplished by presenting both fields in the form of a semi-circle or rectangle. The variability of binocular matches is, however, greater than for monocular comparison.

A third technique makes use of a photo-electric circuit.[7] The sensitive surface of the photocell is placed in the plane normally occupied by *S*'s pupil and the voltage generated by the image focused there is recorded. A diffuse surface equal in size to the field lens is illuminated and the light reflected into the photocell located at a distance equal to that between the eye and the field lens. The area of the photocell exposed to this light must be equated with the area of the image of the source previously focused on the photocell. The illumination on the diffuse surface is varied until the flux density of the light reflected on the photocell surface, as indicated by the voltage generated there is equal to the flux density previously produced there by the Maxwellian view system. Under this condition the effective energy entering the *S*'s pupil in the Maxwellian system is equal to that which would enter the pupil from the diffuse source. The luminance of the diffuse source can then be determined in the conventional manner.

*Summary.* The principle of Maxwellian view is advantageously used in visual experimentation when it is desirable to obtain extended visual stimuli of high luminance. Precautions in the use of this system as well as some advantages and disadvantages are discussed. Calibration of the system involves special problems when using conventional photometers. Alternative methods for calibration which make use of monocular comparison, binocular comparison, and a photoelectric circuit are described.

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[6] The author is indebted to Dr. Yun Hsia for the details of this technique.
[7] Described by K. J. W. Craik, The effect of adaptation on differential brightness discrimination, *J. Physiol.*, 92, 1938, 406.

only the light intercepted by the pupil enters the eye. Subjectively, *S* sees the lens (called the field lens) filled with light. With the aid of additional lenses the light can be rendered parallel hence, neglecting absorption in the lens and surface reflections, it can transverse long optical paths without loss. Variations in temporal characteristics, direction, and energy may be produced by modification of this beam by the appropriate shutters, lenses, reflecting surfaces, filters, etc.

An advantage of the Maxwellian view, in addition to its efficiency in transmitting energy from the source to *S*'s eye and the possibilities it offers for manipulation and control of the light, is the elimination of fluctuations in natural pupil size as an experimental variable provided the image of the source in the plane of the pupil is smaller than *S*'s natural pupil. In addition, since light from each point of the source passes through all zones of the lens, irregularities in the source will not affect the uniform appearance of the field lens.[3] It is not advisable, however, for the source to exhibit gross differences in luminances such as would be obtained from a coiled tungsten filament unless the image of the filament is so small as not to be imaged on the edge of the pupil. If the latter situation exists, movements of the eye can result in variations in the total flux reaching the retina as the pupil edge moves across areas of non-uniform flux-density. A disadvantage of the Maxwellian view is the necessity for placing the eye in such a position that the image of the source is centered in the entrance pupil, although this arrangement does permit the presentation of peripheral stimuli without decrease in the effective area of the entrance pupil.[4] Another disadvantage may arise in experiments on visual acuity where the possible additional complication of Abbe diffraction may be introduced by the Maxwellian view optics.[5]

Since most visual photometers (*e.g.* the MacBeth illuminometer) are designed for the calibration of diffuse surfaces, special precautions must be observed if they are to be used in the calibration of Maxwellian view systems. It is necessary, that the appearance of the field lens being calibrated is not changed, that the exit pupil of the photometer and the image of the source in the Maxwellian system be concentric and in the same plane so that the position of the eye is the same for calibration as in the normal use of the system. The aperture-stop of the photometer must also be equal to or smaller than the image of the source in the Maxwellian system that the Maxwellian system and the photometer comparison surface be viewed through the same diameter entrance pupil. This requirement is necessary to satisfy the requirement that specification of luminance be independent of viewing conditions. It is not always possible to satisfy these conditions as the eyepiece of the apparatus may be so constructed as to prevent the proper positioning of the photometer or the aperture-stop of the photometer may be too large. In some cases it may be possible temporarily to alter the design of the apparatus or the photometer so as to satisfy these requirements (*e.g.* by the use of a supplementary lens which

[3] If the image of the source in the plane of the pupil is too small, entoptic phenomena will destroy the even appearance of the field lens. See A. A. Michelson, On the effect of small particles in the vitreous humor, *J. Opt. Soc. Amer.*, 9, 1924, 197.

[4] See the apparatus used by R. T. Brooke, Variations of critical fusion frequency at various retinal locations, *J. Opt. Soc. Amer.*, 41, 1951, 1010.

[5] *E.g.* the apparatus designed by S. Shlaer, The relations between visual acuity and illumination, *J. Gen. Physiol.*, 21, 1937, 165.